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Formulation optimization and characterization of functional *Kemesha*

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ABSTRACT

This study aimed to enhance *Kemesha* by incorporating a blend of composite flours, including germinated haricot bean, ultrasonicated fine-milled pumpkin, CMC (Carboxymethyl cellulose), and common wheat flour. Additionally, a D-optimal design was employed to optimize the formulation and achieve the desired outcome. Protein, fibre, total carotenoid content, and firmness were responses for optimizing *Kemesha* formulation. The numerical optimization and model validation results indicated that it is feasible to use a flour composition of 63.00 g common wheat flour, 19.01 g germinated haricot bean flour, 14.51 g ultrasonicated fine-milled pumpkin flour, and 3.48 g carboxymethyl cellulose (CMC) per 100 g of flour to prepare *Kemesha* with desirability of 0.596. The proximate composition analysis results showed that the optimized *Kemesha* had higher levels of fibre, ash, and protein compared to the control *Kemesha*, whereas the carbohydrate content was significantly lower. The studies on color estimation revealed that the yellow color of the product was slightly increased during the optimization of *Kemesha* (15.09–31.09), while the brightness index was reduced from 89.38 to 74.44. Compared to the control kemesha, the optimized *Kemesha* had a total phenolic, flavonoid, and carotenoid content of 7.47, 3.67, and 149.20 times greater. The cooking loss (4.95%) and water absorption (220.68%) of optimized *Kemesha* were improved compared to control *Kemesha*. The composite significantly improved the sensory qualities of both raw and cooked *Kemesha*, including surface smoothness, resistance to break, appearance, texture, color, and overall acceptance.

1. Introduction

Kemesha is traditionally produced and consumed in different parts of the Arsi zone, Ethiopia. It is prepared from common wheat flour and water through traditional processing steps of mixing, sheeting, rolling, cutting, and sun-drying. All age groups of people consume it. *Kemesha* was utilized as dry food for transit, for household consumption, during festive events like festivals and wedding ceremonies, and as a source of revenue for a small minority in the Arsi zone. Presently, the processing and consumption of *Kemesha* are village-based, and it has been underutilized. Due to its gluten content, wheat flour is the preferred raw material for making Kemesha, as it is well-suited for dough development and prevents disintegration during the cooking process [1]. *Kemesha* is currently underutilized due to laborious, inadequate hygienic practices during and after processing, long drying time, low nutritional value, and unattractive presentation. Products made from wheat are typically rich in carbohydrates but poor in fibre, protein, minerals, vitamins, and phenolic

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compounds, which frequently causes nutrient imbalances in consumers [2]. Nowadays, consumers worldwide have shown increasing interest in reducing disease risks by consuming health-promoting dietary ingredients [3] along with fulfilling their basic nutrition requirements [4]. This is why foods today are expected to do more than just satisfy hunger and deliver essential nutrients; they are also expected to prevent diseases linked to poor nutrition and improve customers' physical and emotional well-being [5,6]. In this context, functional foods present a remarkable opportunity to enhance the quality of products. In addition to dietary fibre, organic micronutrients like carotenoids, polyphenolics, tocopherols, vitamins C, minerals, organic acids, and others are primarily responsible for the health benefits of plant-based diets [7]. Specifically, phenolics and carotenoids have the potential to provide health advantages by scavenging reactive oxygen species and safeguarding against degenerative diseases such as cancer and cardiovascular diseases [8]. Over the past few decades, there has been an escalating consumer preference for wheat-based products such as pasta and noodles, considering them added value by using both animal and plant products [9]. Likewise, to enhance the nutritional value of *Kemesha*, it is necessary to incorporate ingredients that are high in protein, fiber, and bioactive compounds, such as haricot bean [10,11] and pumpkin flour [12].

Investigations on nutritional, functional, and phytochemical properties of four improved varieties of haricot beans (*Phaseolus vulgaris*) and pretreated pumpkin have underlined the importance of these crops on the human diet for their high protein, fibre, bioactive component and carbohydrates content, which makes this food a good source of nutrients [11–13]. As a matter of fact, several clinical studies show that eating enough fruits and vegetables has positive benefits on the body, acting as a preventative measure for conditions including cataracts, constipation, asthma, cancer, and respiratory (asthma and bronchitis) diseases [14]. To achieve this goal, it is essential to engage in the development and investigation of novel fruit-based *Kemesha* products that possess desirable nutritional, functional, and sensory attributes. The proportion of alternative flours (germinated haricot bean, ultrasonicated fine-milled pumpkin, and carboxymethyl cellulose (CMC)) that can substitute common wheat flour in the *Kemesha* recipe should strike a balance between achieving nutritional enhancement and maintaining satisfactory sensory characteristics. In order to reduce the price of *Kemesha* and make it more accessible to low-income people, it is also necessary to partially substitute wheat with less expensive food crops like pumpkin and haricot bean. Including germinated legumes, especially beans, into cereal-based products could be a good option for increasing the nutritional intake of people [13]. They have a significant role in human nutrition, especially in the diets of low-income populations in developing nations, since they are affordable protein sources [15]. Haricot beans contain about 23.11–27.96% protein which is about two-fold higher than wheat and is also reported to be a good source of bioactive components [11].

It is well recognized that reducing the amount of gluten in a product made from wheat by adding more haricot and pumpkin flour does not improve *Kemesha's* sensory or cooking qualities. As a result, carboxymethyl cellulose, a hydrocolloid, must be added to successfully substitute the gluten in *Kemesha*. The literature also noted that a substance suitable to produce a cohesive structure could overcome the absence of gluten [14]. Generally, using structuring agents may yield acceptable *Kemesha* with good texture and minimum cooking loss [16]. Despite the previous research attempts to promote the partial substitution of common bean flour in pasta and noodles, there remains a significant gap in our knowledge when it comes to the use of germinated haricot bean flour and ultrasonicated fine-milled pumpkin flour in *Kemesha* processing. The present investigation was undertaken to optimize functional *Kemesha* of high nutritive value comprising germinated haricot bean, ultrasonicated fine-milled pumpkin flour, carboxymethyl cellulose (CMC), and common wheat flour by using a D-optimal mixture design. Furthermore, the physical, chemical, and acceptability properties of the optimized *Kemesha* were evaluated to assess its overall quality. This comprehensive evaluation allowed the researchers to gain insights into the characteristics of the optimized *Kemesha* and its potential for further development.

2. Material and methods

2.1. Material collection and preparation

Common wheat flour, pumpkin, and carboxymethyl cellulose were procured from the local market in Addis Ababa, Ethiopia. Haricot bean seeds (SAB 632 variety) were brought from Awash Melkassa Agricultural Research Center. Germinated haricot bean flour was prepared as per the method used by Wodajo and Emire [11], but ultrasonicated fine-milled pumpkin flour was prepared after pumpkin slices $(15 \times 15 \times 4)\ \mathrm{mm}^3$ were pretreated for 20 min in an ultrasonic bath (Model-EU-28, Akin Electronic, Turkey) followed by microwave (Model-CE107BT, Samsung, Thailand) blanching for 6 min at 300W and then dried at 60 °C and 1.2 m/s airflow by a fluidized bed drier for 121 min [17]. The sliced dried pumpkin was milled coarsely by a hammer mill (Model BH24 1DY, Armfield, England), and then the flours were screened through 500 μm sieves to separate granulates. The resulting coarser flours were micronized using ball-milling (Planetary type ball mill, PM 100; Restch, Germany) at 300 r min^{-1} for 15 min three times with an interval of 30 min to avoid flour overheating. Using carboxymethyl cellulose as a process control agent, the stainless steel container was filled to around two thirds of its capacity with the pumpkin flour and five times the weight in stainless steel balls ($\Phi = 10$ mm). The milled flour was also split into distinct particles size fractions (250–150, 150–100, 100–75, and <75 μm particle size) using a set of screen sieved with the vibratory sieve shaker for 5 min. The milled flour obtained was stored at 4 °C in brown zipped bags until further analysis. All chemicals were analytical grade.

2.2. Experimental design

This study was conducted to find an appropriate ratio of four components: common wheat flour, germinated haricot bean flour, ultrasonicated fine-milled pumpkin flour, and carboxy methyl cellulose to prepare functional kemesha with optimum nutritional content and acceptability attributes. A total of twenty treatment combinations were generated using a D-optimal mixture design that was used to find the appropriate ratio. The percentage of the lower and upper range of the ingredients includes 61%–80 % for common wheat flour (CWF), 10%–30 % for germinated haricot bean flour (GHBF), 5%–20 % for ultrasonicated fine-milled pumpkin flour (UFPF), and 2–4% for carboxymethyl cellulose (CMC). Table 1 displays the composition of each blend calculated from the experimental design. The amount of components was selected based on similar available literature as well as by preliminary tests. Effects of wheat flour, germinated haricot bean flour, ultrasonicated fine-milled pumpkin flour, and carboxy methyl cellulose on the protein (Y_1), fibre (Y_2), total carotenoid content (Y_3), and firmness (Y_4) of the kemesha were investigated, and the optimum mixture was selected. The statistical parameters used in evaluating and selecting the best-fitted model were coefficient of determination (R^2), adjusted coefficient of determination (adjusted-R^2), coefficient of variation (C.V), standard deviation, predicted coefficient of determination (predicted R^2), predicted residual sum of squares (PRESS), regression data (P value and F value) and lack-of-fit. The analysis of variance (ANOVA) was used to determine the significant difference between linear, quadratic, and interaction terms of independent factors. A contour plot was created to visualize the concept more clearly by putting a single factor constant at the central point while changing the other three variables within the experimental range. Also, a three-dimensional response surface graph for the model's desirability was generated by Design-Expert Software Version 13.0 for a better explanation. The optimal *Kemesha* preparation was achieved by combining set goals of all quality parameters into an overall desirability function. To confirm the model's validity, the experiment was conducted at optimum values of processing variables, and obtained responses were then compared with predicted values of the responses.

After selecting the optimal *Kemesha* (OK) based on protein (Y_1), fibre (Y_2), total carotenoid content (Y_3), and firmness (Y_4), its physicochemical properties, nutritional value, phytochemical activity, cooking, textural and sensory attributes were compared with the control sample.

$$Y = \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \beta_{12} X_1 X_2 + \beta_{13} X_1 X_3 + \beta_{14} X_1 X_4 + \beta_{23} X_2 X_3 + \beta_{24} X_2 X_4 + \beta_{34} X_3 X_4 \qquad 1$$

where Y = the predicted variable, $X_{1,2,3,4}$ = the proportion of the four flours in the mixture, β's = the coefficient of the linear and quadratic terms of the model.

For verification of the model, the difference between the predicted and actual values or the relative standard error (RSE) can be calculated by using the following equation (Equation (2)):

$$RSE\ \% = \frac{Actual\ value - Predicted\ value}{Predicted\ value} \qquad 2$$

2.3. *Preparation of functional Kemesha*

The composite flours were added together in proportion given by design (Table 1), with small amounts of each flour added gradually while mixing slowly to prevent aggregation. The mixed flour samples were packed and sealed in brown bags. The process outlined in Fig. 1 was used to produce *Kemesha,* which entailed blending 100 g of different flours with 35 mL of water. Carboxymethyl cellulose (CMC) was dispersed in cold water and added to the recipe in the amount given by the design in Table 1 as a flour blend replacement. The mixtures were thoroughly worked to form a consistent dough. The formed dough was allowed to rest for 15 min in a

Table 1
Experimental design showing the doses of each formulated blend and response each runs.

Run	CWF	GHBF	UFPF	CMC	Protein (%)	Fibre (%)	TCC (μg/g)	Firmness (g)
1	80	13	5	2	11.71	2.65	5.94	994.93
2	68	10	20	2	9.77	5.35	28.12	882.85
3	68.5909	13.4545	15.5	2.45455	11.02	4.83	21.75	1025.54
4	*66*	*10*	*20*	*4*	*9.68*	*5.18*	*28.12*	*1115.34*
5	63	30	5	2	13.64	3.62	8.01	981.77
6	61	30	5	4	13.13	3.42	6.65	1141.34
7	69.3909	16.0545	11.1	3.45455	11.66	4.08	15.67	1187.47
8	74.5909	13.9545	8	3.45455	11.52	3.82	11.23	1224.71
9	80	11	5	4	10.92	2.95	5.12	1260.46
10	65.0909	23.4545	8	3.45455	12.81	3.96	11.54	1176.34
11	*66*	*10*	*20*	*4*	*9.54*	*5.18*	*28.12*	*1116.34*
12	61	16	20	3	10.51	5.88	29.21	944.43
13	61	23.5	13.5	2	12.22	4.64	19.86	922.56
14	63	30	5	2	13.58	3.76	7.21	965.77
15	80	13	5	2	11.78	2.69	5.94	995.93
16	70.5	20.5	5	4	12.68	3.08	6.23	1248.32
17	*65.0909*	*16.9545*	*15.5*	*2.45455*	*11.18*	*4.99*	*22.12*	*1010.21*
18	73.5	10	13.5	3	10.23	4.44	19.11	1157.25
19	61	16	20	3	10.61	5.78	29.21	943.43
20	61	30	5	4	13.18	3.47	7.21	1141.34

CMC, carboxymethyl cellulose; CWF, Common wheat flour; GHBF, Germinated haricot bean flour; UFPF, Ultrasonicated fine-milled pumpkin flour; TCC, Total carotenoid content.

closed plastic bag, then passing small portions (50 g) of kneaded flattened sheets of dough were through the pasta machine (Imperia Tipo Lusso SP150, Torino, Italy) at decreasing thicknesses (numbers 2, 3, and 4, respectively). The dough was folded into thirds and sent through again. It was then folded in half, run through, and cut into small manageable lengths. The thin, flattened sheets were passed through the fettuccine cutter to form *Kemesha* strands, which were 1.5 cm in length and 1.6 mm in width. The slit and cut strands were put in cleaned aluminum trays and then oven dried at 50 °C for 2:10 h to safe moisture content (<12 %). The dried *Kemesha* was stored in brown bags at room temperature until further use.

2.4. Physical characteristics

Ten (10) strips of *Kemesha* were taken for thickness and length measurements with a digital vernier caliper (TA, M5 0–300 mm, China) of 0.01 mm precision, and the average was reported. A water activity meter (HD-3A, NanBei, China) was used to gauge *Kemesha's* water activity at room temperature. Before estimating the water activity, *Kemesha* samples were comminuted and homogenized. After letting the produced slurry stand for 10 min while being constantly stirred, the pH of the comminuted *Kemesha* was

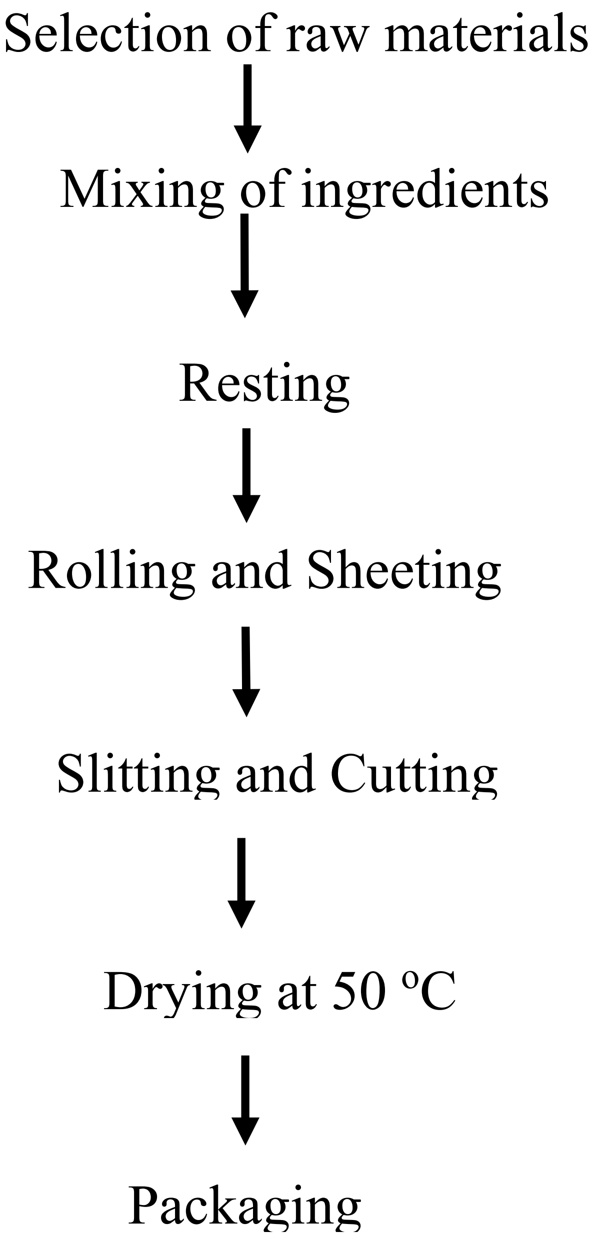

Fig. 1. Flowchart of k*emesha* processing methods.

measured by blending 10 g in a beaker containing 25 mL of distilled water with a pH meter (BANTE Multiparameter, China) in accordance with AOAC [18].

Color measurements on *Kemesha* samples were carried out according to Cappa et al. [19] using a Minolta colorimeter (3NH Technology Co., LTD, China). The dried *Kemesha* sample (120 g) was milled (BH24 1DY, Armfield, England) and sieved through a 500 μm sieve. The flour was then put into plastic Petri dishes, where the top was manually leveled to the brim of the dish, and a plastic film was then snugly placed on top. The black and white tile was used for instrument calibration before color measurement. Color coordinates L*, *a**, and *b** were measured at seven points on the surface. Results were expressed in the CIELAB space as L* (lightness; 0 = black, 100 = white), a* (+a = redness, -a = greenness) and b* (+b = yellowness, -b = blueness) values. Results were also expressed as color differential (*ΔE*) between the control (*Kemesha* with common wheat flour only) and the optimized kemesha, calculated by using the following equation (Equation (3))according to Jayasena and Nasar-Abbas [20]:

$$\Delta\mathrm{E} = \left((\Delta L)^2 + (\Delta a)^2 + (\Delta b)^2\right)^{1/2} \quad 3$$

where DL* = L_1* - L_2*, Da* = a_1* - a_2* and Db* = b_1* - b_2*; while L*, a* and b* values of control were subscripted by 1, but the optimized one was subscripted by 2.

The Chroma and Hue angle was determined using the following equations (Equations (4) and (5)) to demonstrate the relationship between a* and b* [21]:

$$\mathrm{Chroma}(\mathrm{C}*) = \left[(a)^2 + (b)^2\right]^{1/2} \quad 4$$

$$\mathrm{H}^* = tan^{-1}(b/a) \quad 5$$

2.5. *Proximate composition of the control and optimized Kemesha*

According to established procedures of AOAC [18], the approximate composition of the flour samples was ascertained. The samples were oven-dried (Model 10-D1391/AD, SCA) at 105 °C for 18 h to achieve constant weight to estimate the moisture content (MC). The percent crude protein (% CP) was determined using an automatic Kjeldahl analyzer (K1160, Hanon, China), and the acquired percent nitrogen (N) was multiplied by 6.25 to determine the percentage crude protein (% CP). The Soxhlet extractor method was used to calculate the fat content. After burning the samples at 550 °C for 4 h in a muffle furnace (MKF-07, Natek, Turkey), the mass difference was calculated to determine the percentage of ash (%). Dilute acid and alkali hydrolysis calculated crude fiber percentage (% CF) (BXB-06Guangzhou, China). Carbohydrate was calculated by difference.

2.6. *Phytochemical properties of the control and optimized Kemesha*

First, the methanol extracts were prepared from milled *Kemesha* flour, according to Erbiai et al. [22]. A temperature shaker incubator (ZHWY-103B) was used to extract 10 g of flour with 100 mL of methanol over the course of 24 h at 25 °C and 150 rpm. The cleared mixture was then passed through the Whatman No. 1 paper. The deposit was extracted with two additional 100 mL portions of methanol described above. The methanolic extracts were vaporized using a Rota evaporator (R-300, Buchi, Switzerland) at 40 °C until dry, then redissolved in methanol at a 50 mg/mL concentration and kept at 4 °C for later use. Then the total phenolic content was determined in triplicate using the Folin–Ciocalteu method at a wavelength of 735 nm with gallic acid used as a standard. At the same time, the total flavonoid concentration was determined using the colorimetric method with quercetin used as standard at a wavelength of 510 nm, as described by Minuye et al. [23]. By employing ascorbic acid as a standard without extract or control, antioxidant activities were assessed using the DPPH techniques [24]. For the quantitative analysis of antioxidant activities, a calibration curve was obtained by injection of known concentrations of ascorbic acid standards ($y = 474.36x+16.73$, $R^2 = 0.91$). The amount of total carotenoid was calculated using the de Carvalho et al. [25] approach and expressed as g per g of dry matter. Expect DPPH; all analysis was carried out in triplicate.

2.7. *Evaluation of the Kemesha cooking qualities*

Water absorption, cooking loss, and volume increase of *Kemesha* were measured according to the AACC methods [26] by using the following equations (Equation (6),7 and 8), respectively. After cooking 10 g of fresh *Kemesha* for the appropriate amount of time in 100 mL of distilled water, cooling for 1 min with cold water, and removing the water for 30 s, the water absorption rate was determined. After determining the water absorption rate, the cooking loss was calculated following a 24-h drying period at 105 °C with the leftover water. The volume rise rate was determined by adding 10 g of fresh *Kemesha* and 10 g of cooked *Kemesha*, respectively, to a 500 mL measuring cylinder filled with 200 mL of distilled water. All the analyses were conducted in triplicate. The respective formulae used in the calculations are as follows:

$$Water\ absorption(\%) = \frac{\text{Weight of cooked } Kemesha(\text{g}) - \text{Weightof fresh } Kemesha\ (\text{g})}{\text{Weight of fresh Kemsha (g)}} * 100 \quad 6$$

$$Cooking\ loss(\%) = \frac{\text{Remaining solid content after drying (g)}}{\text{Weight of fresh Kemsha (g)}} * 100 \quad 7$$

$$Volume\ increase(\%) = \frac{\text{Volume of cooked } kemesha\ (mL) - \text{Volume of fresh } Kemesha \text{ (mL)}}{\text{Volume of fresh Kemsha (mL)}} * 100 \quad 8$$

2.8. Kemesha texture profile analysis

According to Larrosa et al. [27], a 36 mm diameter flat-ended cylindrical probe (P/36) was used in two compression cycle tests to measure the texture of cooked *Kemesha*. *Kemesha* (10 g) was cooked in 100 g of water using an induction oven (RBE-22H, Rinnai, Incheon, Korea) to optimum cooking time (6 min for control and 5.3 min for optimized *Kemesha*). After cooling in a sieve for 30 s, the cooked *Kemesha* was left in there for two to 3 min to drain off the remaining water. *Kemesha* of 1.6 mm thickness and 1.5 cm length were prepared for texture profile analysis using a texture analyzer (TA-XTplus, Stable Micro Systems Ltd., Godalming, UK). The test conditions were as follows: 1 mm/s pre-test speed, 1 mm/s test speed, 5 mm/s post-test speed, 80 % strain, and 20 g trigger force. From the force-time curve, the parameters calculated were hardness, adhesiveness, springiness, cohesiveness, and chewiness [28]. Measurements were replicated 10 times for each treatment.

2.9. Sensory evaluation of the control and optimized Kemesha

Panelists familiar with the *Kemesha* among the students and employees of the University of Wolkite, Ethiopia, voluntarily participated in evaluating both dried and cooked *Kemesha* samples using nine-point hedonic scales with 1- dislike extremely to 9 - like extremely (appendix). For cooked *Kemesha*, a 100 g sample was boiled (98–100 °C) in 500 mL of unsalted water while being watched until the *Kemesha's* core vanished after being squeezed between two transparent glass slides for 6 min for control and 5.3 min for optimized *Kemesha*. The extra cooking and cooling water were then drained from the sample. The samples were then stored for not more than 30 min in tightly covered plastic food containers before testing. Ten panelists were given samples of *Kemesha* to judge the texture, color, odor, appearance, and general acceptability of cooked *kemesha* as well as the smoothness, resistance to breaking, odor, appearance, and overall acceptability of raw *kemesha*.

3. Results and discussions

Then, prior to optimization preliminary investigations were carried out to identify the suitable variables for the response and determine the ranges of these variables in the *Kemesha* formulation. The preferred *Kemesha* from the acceptability test was used as a control. Carboxymethyl cellulose (CMC) is selected as the structuring agent. According to Liu et al. [29] and Hu et al., [30] adding CMC greatly improved the texture and cooking quality of the noodles by increasing their firmness, reducing their stickiness, improving their chewiness, and increasing their elasticity.

3.1. Nutritional and phytochemical composition of raw materials

Table 2 shows the chemical composition of the raw materials of *kemesha*. According to the investigation, while germinated haricot bean (SAB 632 variety) flour had the highest protein content (26.740.82), ultrasonicated fine-milled pumpkin flour had the highest levels of bioactive components and fibre, which improve the functional qualities of a food product. Carboxymethyl cellulose (CMC) was very effective on texture due to its network-forming capacity [31].

3.2. Fitting for the best model

Experimental results for the response variables of kemesha preparation are shown in Table 1. The best model was selected based on a low standard deviation, a low predicted sum of squares, and a high R-squared [32]. While the total amount of carotenes could be explained by a linear model, protein, fibre, and sample firmness could all be explained by quadratic models. The ANOVA showed that lack of fit was insignificant for all the D-optimal mixture designs at a 95% confidence level. The lack of fit test measures how well a

Table 2
Chemical composition of raw materials.

Activities	CWF	GHBF	UFPF
Protein	9.61 ± 0.36^b	26.74 ± 0.72^a	9.05 ± 0.38^b
Crude fibre	1.83 ± 0.08^c	6.20 ± 0.32^b	14.22 ± 0.24^a
Total Carotenoids μg/g	0.14 ± 0.04^b	1.12 ± 0.05^b	139.41 ± 0.88^a
Total phenols mgGA/g	0.17 ± 0.03^c	0.84 ± 0.05^b	6.47 ± 0.29^a
Total flavonoids mgCE/g	0.25 ± 0.05^c	3.53 ± 0.05^a	1.91 ± 0.04^b

All values are mean ± standard deviation. This means sharing the same letters in raw are not significantly different from each other (student-t-test, $p < 0.05$; CWF, common wheat flour; GHBF, germinated SAB 632 haricot bean flour, UFPF, Ultrasonicated pumpkin flour milled to <75 μm.

model captures experimental domain data during times when such data were not included in the regression [33]. The CV indicates the relative dispersion of the experimental points from the model's prediction. According to Gull, Prasad and Kumar [34], the model was considered adequate when the multiple coefficients of correlation (R^2) were more than 93 %, and the lack of fit test was non-significant. The (R^2) values for the responses, i.e., protein, fibre, total carotenoid, and firmness, were 0.97, 0.99, 0.99, and 0.99. A high proportion of variability ($R^2 > 0.97$) in the response models was obtained (Table 3). Adding a variable to the model always increase R^2, regardless of whether the additional variable is statistically significant or not, so a large value of R^2 does not always imply that the regression model is a good one.

Thus, it is preferred to use an adj-R^2 to evaluate the model adequacy, and it should be over 90% [33]. Table 3 shows that R^2 and adj-R^2 values for the models did not differ dramatically, indicating that non-significant terms were not included in the model. The models' sufficiency precision values were greater than 4, and it may be inferred that they can be used to track the design space [35]. Thus all four responses were considered adequate to describe the effect of variables on the quality of *Kemesha*. Fig. 2(a–l) indicates the difference in fits (DFFITS), Leverages, and Cook's distance for firmness, fiber, protein, and total carotenoid contents. As can be seen, all of the leverage values are lower than 0.50, so there are no outliers or unanticipated errors in the model. Also, the cook's distance and DFFITS plots confirmed the model's reliability because the values are within the specified range [32]. The estimated regression coefficients of the proposed models for each response are given in Table 4. The coefficient estimate shows the severity of one factor when all other variables are held constant by estimating the expected change in response per unit change in factor value [15].

3.3. Effect of variables on the protein content of Kemesha

According to Fig. 3 (a), the greatest effect on protein content was related to geminated haricot bean flour (GHBF). A quadratic model effectively explained how the protein content and blend proportions relate to one another ($R^2 = 0.97$ and adjust-$R^2 = 0.96$). The linear blends significantly affected the protein content. In contrast to the wheat-pumpkin flour blends, the binary (wheat-haricot bean flour) mix was synergistic and positively affected the volume for a maximal response of protein content (Fig. 3(a)). As demonstrated in Table 1, the protein content ranged from 9.54 % to 13.64 %. The maximum protein content was in the formulation consisted of 66 % common wheat flour (CWF), 30 % geminated haricot bean flour (GHBF), 5 % ultrasonicated fine-milled pumpkin flour (UFPF), and 2 % Carboxymethyl cellulose (CMC) (run 5, protein content: 13.64). According to the findings, the mixture of these ingredients improved the protein content of *Kemesha* by 53.25% compared to the control kemesha. Protein content increased significantly when the proportion of GHBF flour increased; however, it fell slightly when the fraction of UFPF flour increased. Previously similar reports were done on pasta and noodle protein enhancement using common bean flour [36,37]. Moreover, Shogren, Hareland, and Wu [38] revealed that the protein content of pasta increased by 54 % when soy was added to it (at a level of 50 %) compared to the control sample. The greater protein level of the sprouted haricot bean flour used in creating composite flour may be responsible for the rise in protein content in *Kemesha*.

3.4. Effect of variables on the fibre content of Kemesha

The fibre content of *Kemesha* ranged from 2.65 % to 5.88 %, as shown in Table 1. In comparison to the control, *Kemesha* from a blend of 61 % CWF, 16 % GHBF, 20 % UFPF, and 3 % Carboxymethyl cellulose (CMC) (run 12) showed a considerably ($p < 0.05$) higher fibre content. These combinations increased the amount of fiber by 7.35 fold compared to the control sample. According to the fibre content analysis, ultrasonicated fine-milled pumpkin flour (UFPF) presented an influential effect on the *Kemesha* fibre content, with a drop in the percentage of wheat flour, the fiber content also rose. The relationship between the blend proportions and the fibre content was adequately described by a quadratic model Table 3 with $R^2 = 0.99$ and aduj- $R^2 = 0.99$. The fibre content is significantly ($P > 0.05$) affected by the linear mixes (Table 4) (Fig. 3(b)). With the exception of the binary (wheat-haricot bean flour) blend, which had a minimal effect on fiber content, the other blends had a favorable impact on fiber content Fig. 3(b). The fiber content of *Kemesha* showed an increasing trend with a parallel increase in the proportion of ultrasonicated fine-milled pumpkin flour due to its high fiber content (14.22 ± 0.30) as compared to geminated haricot bean flour (GHBF) (6.2 ± 0.40) and common wheat flour (1.83 ± 0.10). Fig. 3 (b) shows that the amount of fibre significantly increased when the ratio of pumpkin and haricot bean flour was increased but

Table 3
ANOVA showing the linear, quadratic, and lack of fit of the response variables.

	Protein	Fibre	Total carotenoid	Hardness
Model (P value)	<0.0001	<0.0001	<0.0001	<0.0001
Model (F value)	397.39	397.23	3619.69	566.71
R^2	0.97	0.99	0.99	0.99
Adjusted R^2	0.97	0.99	0.99	0.99
Predicted R^2	0.96	0.98	0.98	0.98
C.V%	0.820	1.75	2.46	0.6692
Lack-of-fit (P value)	0.1010	0.2061	0.2560	0.1285
Lack-of-fit (F value)	3.43	2.18	1.86	2.97
Standard deviation	0.095	0.0732	0.3894	7.17
Press	0.287	0.1969	3.80	1663.00

$P < 0.05$ is significant, $P > 0.05$ is not significant; PRESS, predicted residual sum of squares; C.V, coefficient of variation.

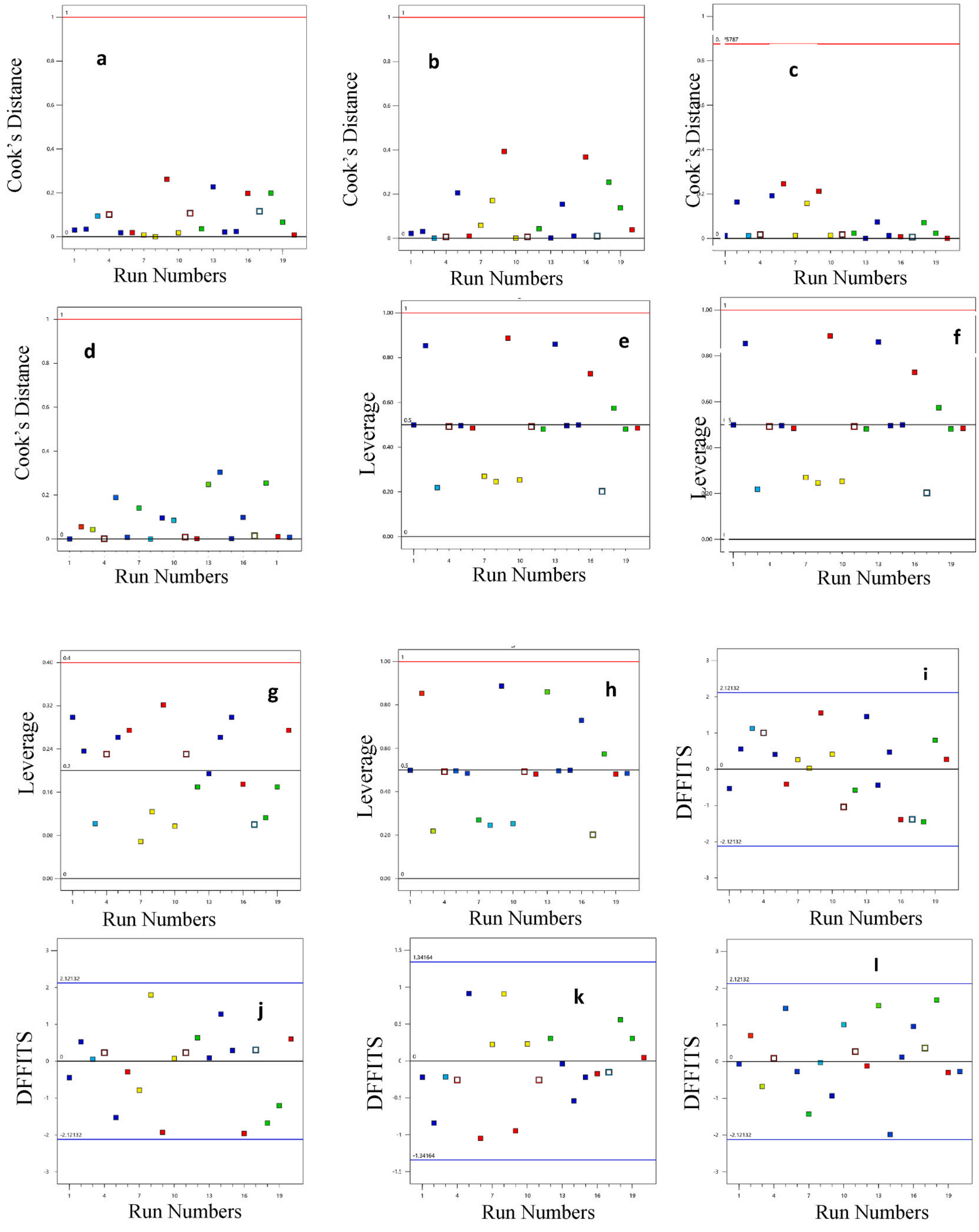

Fig. 2. Cook's distance, Leverages, and difference in fits (DFFITS) for protein (a, e, and i), fiber (b, f, and j), total carotenoid content (c, g, and k), and hardness (d, h, and l) models.

reduced when the ratio of wheat flour was increased. Also, a similar trend of rising fibre content together with rising legume content for composite flour has been documented [39]. According to MA et al. [40], adding pumpkin flour to wheat flour increases the fibre content of biscuits. According to Gull, Prasad and Kumar [34], incorporating high-fibre material enhances pasta's nutritional and functional quality. Since kemesha is regarded as a traditional cuisine made primarily from common wheat flour, this is crucial to improving the fibre content from underutilized pumpkin and haricot bean for producers.

3.5. Effect of variables on the carotenoid content of Kemesha

The carotenoid content of developed kemesha products ranged from 5.12 to 29.21 μg/g. The statistical analysis suggested a linear

Table 4
The Estimated regression coefficients of the proposed models for each response.

Variable	Protein	Fibre	TCC	Firmness
A	10.96^a	2.55^a	5.80^a	969.66^a
B	13.54^a	3.85^a	7.69^a	953.77^a
C	8.79^a	7.01^a	39.27^a	615.13^a
D	11.97^a	−197.74^a	2.15^a	−5256.75^a
AB	3.71^a	−0.4139^d	–	235.92^a
AC	1.31^c	−1.15^c	–	710.21^a
AD	−5.10^d	225.33^a	–	10335.45^b
BC	2.09^c	−1.82^b	–	413.05^a
BD	−2.87^d	216.77^a	–	9119.22^b
CD	−0.9046^d	214.64^a	–	10153.58^b

Note: Common wheat flour (A), Germinated haricot bean flour (B), ultrasonicated fine-milled pumpkin flour (C), Carboxy methyl cellulose (D), total carotenoid content (TCC).
a, Significant at 0.0001 levels, b, Significant at 0.01 levels, c, Significant at 0.05 levels, d, Not Significant at 0.05 levels.

model with $p < 0.001$. The model shows the goodness of fit because it was considerable, and lack-of-fit was insignificant (Table 3). The highest carotenoid content was observed in the combination of 61 % common wheat flour (CWF), 16 % geminated haricot bean flour (GHBF), 20 % UFPF, and 3 % of CMC (Table 1), and the lowest was found in control (0.14 μg/g) (Table 6). The total carotenoid content was positively impacted by UFPF flour, followed by GHBF flour, but negatively impacted by common wheat flour, as shown in Fig. 2 (c), where the linear blend coefficients significantly ($p < 0.05$) affected the score. As previously mentioned, this is owing to the pumpkin's high carotenoid concentration [12], and its integration into kemesha at various degrees considerably boosted the carotene content. With the economically effective utilization of underutilized greens, enriching low-carotenoid content foods with high-carotenoid foods like pumpkin may help fight blindness issues [41]. Also, adding more pumpkin flour improved the food's functional qualities regarding its phytochemical content [42]. In a related study, MA et al. [40] found that adding pumpkin flour to biscuits raises their carotenoid concentrations. But as depicted in Fig. 3 (d), adding carboxymethyl cellulose to the kemesha did not significantly affect total carotenoid content.

3.6. *Effect of variables on the firmness of Kemesha*

Firmness is among the most crucial qualities of *Kemesha*. Table 3 shows that the lack-of-fit is insignificant, but the model is significant. This means that the possibility of an error occurring is low. Table 1 displays that the firmness of the *Kemesha* varied between 882.85 g (run 2) and 1260.46 g (run 9). The hardness of run 9 was 1.39 times higher than the control sample. As shown in Fig. 3 (e and f), firmness decreases as the proportion of both ultrasonicated fine-milled pumpkin flour (UFPF) and geminated haricot bean flour (GHBF) increases, but with an increase of carboxymethyl cellulose (CMC) percentage in the blends, the *Kemesha* gets harder and harder. Regression coefficient Table 4 showed that the firmness of *Kemesha* samples was significantly affected ($p \leq 0.05$) by the CMC at a quadratic level. Generally, firmness is reduced by replacing common wheat flour with pumpkin and haricot bean flour by keeping CMC constant (Fig. 3 (e)). The general trend observed is a progressive reduction in *Kemesha* firmness with increasing fiber concentration. The disruption of the protein starch matrix within the *Kemesha* microstructure by fibre, as in pasta, may be responsible for the drop in hardness [43]. It could be associated with a weakening gluten network [42] and as well as poor availability of water to develop the gluten network [44]. According to Gatta et al. [45], foreign proteins that prevent the development of gluten-starch complexes may lessen the stiffness. In addition, the firmness response of the *Kemesha* reached the maximum value when the proportion of CMC increased. The formation of complexes may cause this due to the interaction of hydrophilic groups on starch, CMC, fat, and protein, thereby improving the structure of *Kemesha* [46,47]. Similar experiments showed that adding xanthan gum and locust bean gum at 2.5–10 % significantly increased the stiffness of pasta [20]. As stated by Widelska et al. [48], hydrocolloids' binding effect of water-soluble starch improved the texture of gluten-free pasta. CMC can increase the viscosity of the *Kemesha* dough, which can affect the texture of the final product. Higher viscosity can lead to a firmer and more elastic texture, which is desirable in *Kemesha* products. According to Kamali Rousta et al. [32], firmness depends on the level, kind, and interaction of the flours incorporated with the product.

3.7. *Optimized level of ingredients*

To produce functional *Kemesha*, Design-Expert Software (version 13.0) was used to determine the ideal level of variable as well as the extrapolative value of responses in accordance with the predetermined goals with maximum desirability function. A good quality functional *Kemesha* should have a high level of fibre, total carotenoid content (TCC), protein content, and firmness, so the criteria target for responses is maximum. Optimization was done by maximizing the amount of protein, fiber, total carotenoid content, and firmness. The numerical response analysis found that optimum values were 63.00 g of CWF, 19.01 g of geminated haricot bean flour (GHBF), 14.51 g of ultrasonicated fine-milled pumpkin flour (UFPF), and 3.48 g of carboxymethyl cellulose (CMC) with 0.596 desirabilities (Fig. 4). Desirability demonstrates the effectiveness of the optimization objective function, displaying the program's capacity to satisfy user wishes per the standards established for the finished output to reach a satisfactory compromise [46]. The numerical optimization finds a point that maximizes the desirability function. Protein, fibre, total carotenoid, and firmness had

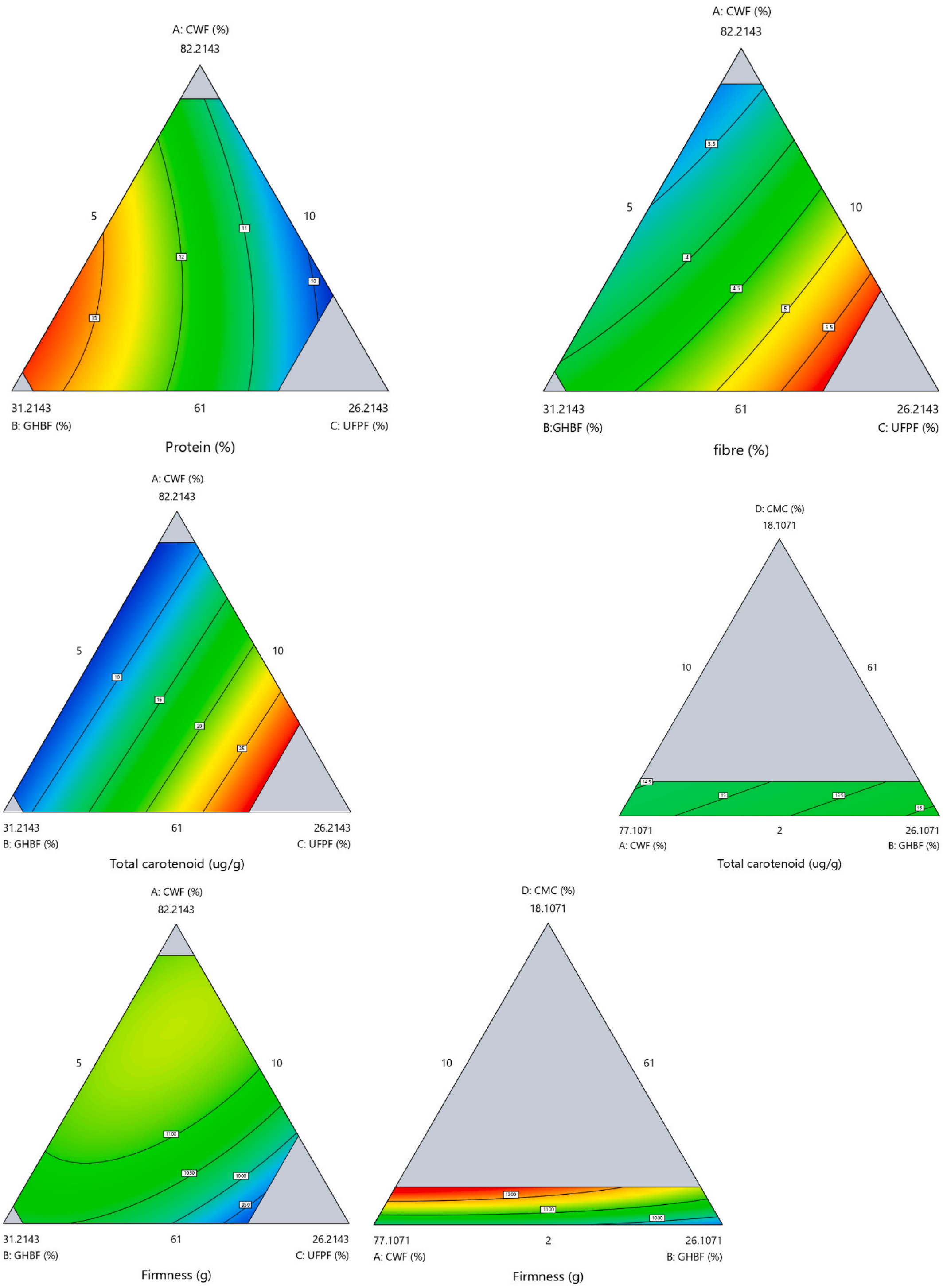

Fig. 3. Contour plots of protein (a), fibre (b), total carotenoids (c) and firmness (d, and e).

predicted values of 11.57 g/100 g, 4.70 g/100 g, 20.79 g/100 g, and 1110.043 g, respectively, under the optimal circumstances. The amount of protein and fibre in the optimal sample was 1.30 and 3.76 times higher than in the control sample. The validation findings showed good agreement between experimental and predicted response values and no statistically significant difference between them, proving the model's applicability (Table 3). Also, if the relative standard error (RSE) (Equation (2)) or the difference between the predicted and actual values derived from the optimal conditions is less than 2 % (Table 5), it demonstrates the validity of the suggested model based on the D-optimal design [49,50].

Table 5
Actual and predicted values of protein, fibre, TCC, and firmness of optimal formulation.

Independent variable				Protein			Fibre			Total carotenoid			Hardness		
CWF (%)	GHBF (%)	UFPF (%)	CMC (%)	Actual value	Predicted value	RSE (%)	Actual value	Predicted value	RSE (%)	Actual value	Predicted value	RSE (%)	Actual value	Predicted value	RSE (%)
63.00	19.01	14.51	3.48	11.64	11.57	0.61	4.81	4.75	1.26	20.89	20.78	0.53	1114.52	1110.57	0.36

Table 6
Proximate and phytochemical composition of control and optimized *kemesha*.

Activities	Control	Optimized
Moisture (%)	9.22 ± 0.85^a	10.03 ± 0.24^a
Ash (%)	2.41 ± 0.27^b	2.95 ± 0.09^a
Fat (%)	2.13 ± 0.14^a	1.75 ± 0.18^b
Protein (%)	8.90 ± 0.62^b	11.64 ± 0.12^a
Fibre (%)	1.25 ± 0.15^b	4.81 ± 0.39^a
CHO (%)	76.08 ± 1.36^a	68.82 ± 0.06^b
TCC (μg/g)	0.143 ± 0.02^b	20.89 ± 1.49^a
TPC (mgGA/g)	0.150 ± 0.03^b	1.12 ± 0.10^a
TFC (mgCE/g)	0.210 ± 0.10^b	0.77 ± 0.21^a

Values are mean ± standard deviation. This means sharing the same letters in raw are not significantly different from each other (student-t-test, $p < 0.05$; CHO; Carbohydrate; TCC, Total carotenoid content; TFC, Total flavonoid content; TPC, Total phenol content.

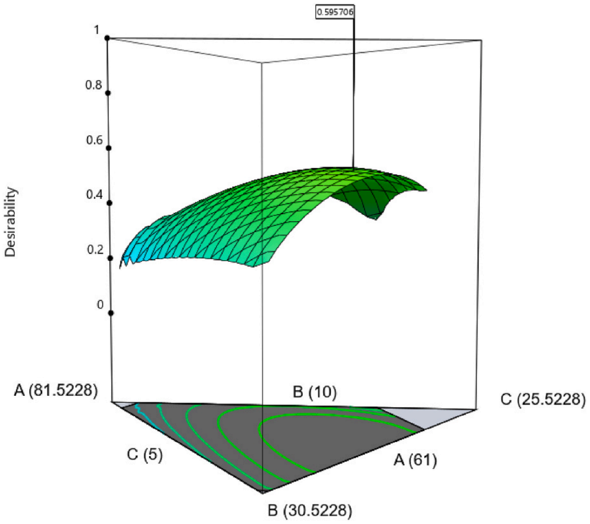

Fig. 4. A 3D plot of the desirability function.

Therefore, the finalized equation (Equation (1)) for each variable generated by Design-Expert 13.0 software is acceptable for use in the *Kemesha* formulation.

3.8. Chemical properties of control and optimized Kemesha

Table 6 indicates that the moisture content of the optimized kemesha sample (10.03 ± 0.24) was found to be slightly but not significantly higher ($P < 0.05$) than that of the control kemesha sample (9.22 ± 0.85). The higher moisture content in optimized kemesha may be due to the higher water-holding capacity of fibres in pumpkin and haricot beans during dough formation. Understanding how a product's water content influences its shelf life is critical since abundant water could encourage the development of harmful microbes [51]. In similar studies, the increase in moisture content with the addition of gums in noodles was also reported by Shere, Devkatte and Pawar [52]. Table 6 depicted that while protein content increased (8.90 ± 0.62 to 11.64 ± 0.12) but fat content slightly decreased (2.13 ± 0.14 to 1.75 ± 0.18) with the incorporation of germinated haricot bean and ultrasonicated fine-milled pumpkin flour in *Kemesha*.

This might be due to a lower fat percentage in haricot bean and pumpkin flour and a higher percentage of protein in germinated haricot bean flour (GHBF) (Table 2). This low-fat level is also appropriate for customers who demand a low-fat diet. The crude fibre content of haricot bean and pumpkin flour-supplemented *Kemesha* was much higher than those prepared from common wheat flour only. As shown in Table 6, there was a prominent increment in crude fiber by 3.85 times as compared to the control *Kemesha*. The addition of haricot bean flour and ultrasonicated fine-milled pumpkin flour, which have higher crude fibre contents than regular wheat flour, is what caused the increase in crude fibre levels. There was a significant difference in carbohydrate content of optimized *Kemesha* and control. In general, carbohydrate content decreased progressively with adding haricot bean and pumpkin flour to kemesha. The considerable reduction may be due to supplementing other nutrients by haricot bean and pumpkin flour. Ash content was also found to be increased significantly from 2.41 ± 0.27 to 2.95 ± 0.09 in optimized kemesha. Another research showed that adding dried pumpkin powder to noodles raised their ash level [53].

3.9. Phytochemical composition of control and optimized *Kemesha*

The rise in degenerative diseases, bad lifestyles, inactivity, and excessive consumption of foods high in fat and sugar are among the current social debates. The development of healthy food products has expanded in response to escalating consumer demand. The communities recognize that the value of food intake should be nutritional and provide more advantages to overall health. One of the most important aspects of functional food research is examining the properties of naturally occurring active components (such antioxidants like polyphenols) in extracts derived from particular food sources. High levels of active ingredients improve food's ability to promote health and improve consumers' quality of life [54–56]. In addition to their basic nutrients, pumpkin and haricot bean flour also include phytochemicals that may have positive health effects [11].

Tables 1 and 6 present the phytochemical compositions of flour and *Kemesha* samples, respectively. Common wheat flour's total phenolic and flavonoid contents were significantly lower ($p < 0.05$) than germinated haricot bean and ultrasonicated fine-milled pumpkin flour. Kemesha that has been modified had considerably greater levels of total phenolic (1.12 mg GAE/g), total flavonoids (0.770.21 mgCE/g), and total carotenoids (20.891.49 g/g) than control *Kemesha*. Fig. 5 illustrates how optimized *Kemesha* has a higher scavenging ability than unimproved Kemesha.

The increment in total phenolic and flavonoid content of optimized *Kemesha* samples may be due to higher phenolic content in ultrasonicated fine-milled pumpkin flour (Table 2). In general, the values of total phenolic content found in the present work were lower than those reported by Gallegos-Infante et al. [57] for pasta made with semolina and common bean flour, respectively. According to a related study, bean flour boosts the amount of phenolic acids and the antioxidant power of pasta dough. Faba seeds are rich in pro-health phytochemicals such as phenolic compounds, which increase the pro-health qualities of functional foods, according to Karkouch et al. [58]. According to research by Fernando-Panchon et al. [59] and Luo et al. [60], field beans' beneficial effects on health are directly related to their high antioxidant content. Given this, common wheat-germinated haricot bean-ultrasonicated fine-milled pumpkin *Kemesha* with the addition of carboxymethyl cellulose (CMC)can be an important source of natural bioactive compounds. Phenolic compound-rich foods have been shown to possess antioxidant properties [54]. The addition of haricot bean and pumpkin flour, which are well-known to be effective sources of antioxidant components, may have contributed to the enhanced antioxidant activity in the case of the optimized *Kemesha* Fig. 5. Due to the contribution of antioxidant activity from both flours, as shown in Fig. 5, the antioxidant activity of optimized *Kemesha* samples increased significantly. According to the findings, mixing haricot bean and pumpkin flours into *Kemesha* would be a practical strategy to market this product rich in phenols. According to Alberto et al. [54] study, which was similar to this one, the DPPH test spaghetti manufactured with common bean flour had a higher value than the control spaghetti.

3.10. Physical properties control and optimized *Kemesha*

Color is a crucial component when evaluating the aesthetic appeal and market worth of food goods. Color values were measured for both raw optimized and control *Kemesha* samples. Control *Kemesha* displayed the highest lightness L* value (89.39 ± 2.24), while optimized *Kemesha* revealed the lowest (74.44 ± 2.50). This decrease in lightness may be due to color contribution from another component, haricot bean, and pumpkin flour. That means both flour samples were darker and greener because of the natural pigment color of the flour. Also, as stated by Han et al. [61]and Gull, Prasad, and Kumar [16], the decline in whiteness may be attributed to an increase in fibre content. Slightly higher values of *L** were obtained for a product prepared from common wheat flour comparable to a product made from durum wheat semolina [62]. Noodles made from semolina flour had a higher yellow hue but were darker compared to the Control *Kemesha*, as evidenced by the respective color parameter values of 68.9 ± 1.5, 1.6 ± 0.4, and 20.8 ± 1.1 for L*, a*, and b* [63]. Optimized *Kemesha* showed the highest a* value (3.62 ± 0.35) compared to control (common wheat flour) *Kemesha* (0.35 ± 0.20). This could be due to the red color contribution of the haricot bean flour [11] and pumpkin flour [53]. As depicted in Table 7, optimized *Kemesha* showed a higher b* value or yellowness (31.09 ± 1.84) as compared to control *Kemesha* (15.09 ± 2.24). This may be due to the carotenoids present in pumpkin flour [12,40]. Incorporating natural pigment not only promotes the sensory features of

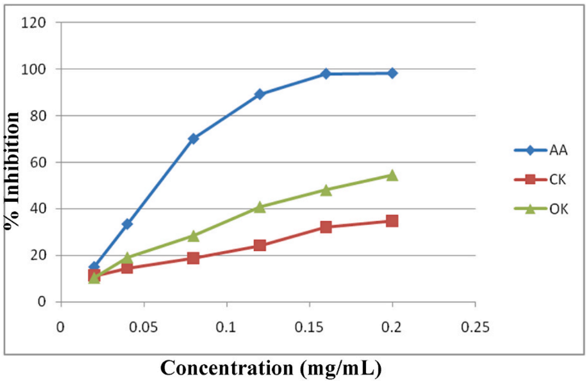

Fig. 5. Free radical scavenging of methanolic extract of *Kemesha* samples and controls (ascorbic acid).

food but also functionally enhances the nutritional quality of food [64]. The chroma index and hue angle for the optimized *Kemesha* (31.30 ± 1.84 and 83.35 ± 0.70) were significantly different ($p < 0.05$) than *Kemesha* prepared only from common wheat flour only (15.09 ± 2.24 and 88.65 ± 0.76). Results obtained for color change indicated that colors are not close to one another, with a relative difference of 22.31 ± 2.63. This difference was associated with using common bean and pumpkin flour, which produced a darker color. The outcomes were better than those found in Gallegos-Infante et al. [57] study on pasta made with common bean flour. Also, it was discovered by Setady et al. [65] that the addition of various additives to pasta noodles improved the color shift.

The Water activity and pH of optimized and control *Kemesha* were not significantly ($p > 0.05$) different from each other. Water activity, however, changed insignificantly from 0.46 ± 0.01 and 0.49 ± 0.02 with optimized *Kemesha* (higher moisture content); these data indicate that CMC binds water within the system. The pH also increased insignificantly from 5.88 ± 0.06 to 5.91 ± 0.07. This might be attributed to when dry beans are germinated, they tend to have a higher pH compared to conventional wheat flour. This is because the enzymes activated during germination break down complex carbohydrates into simpler sugars, which can create a more alkaline environment. As a result, this could potentially lead to an increase in the pH of the *Kemesha* if germinated dry beans are used as an ingredient [66].

3.11. *Texture and cooking properties of control and optimized Kemesha*

The test consists of compressing bite-size pieces of food two times in a motion that simulates the jaw's action and extracting several textural parameters from the resulting force-time curve. Consumer acceptance of cooked *Kemesha* is greatly influenced by its firmness and stickiness. The textural properties of control and optimized *Kemesha* are presented in Table 9.9. The control *Kemesha* displayed the maximum cohesiveness (shows the strength of the internal link) and adhesiveness (24.94 ± 5.22 g*s), whereas the optimized *Kemesha* exhibited the highest firmness (1110.05 ± 59.93), springiness (0.54 ± 0.07), and chewiness (181.80 ± 42.88), in that order. Because it takes more effort to chew before swallowing, *Kemesha*, with a higher degree of firmness, also tends to have higher chewiness values. The optimized *Kemesha* adhesiveness was found to be insignificantly lower than control *Kemesha*s. According to Oduro-Obeng, Fu and Beta [67], adhesiveness is related to the number of starch granules that exudate from the pasta matrix into the cooking water and coat the product's surface. Similar research on pasta by Widelska et al. [48] with the addition of xanthan gum led to the formation of a continuous protein matrix and a stiff protein network that avoids excessive material leaking during cooking and lowers pasta adhesiveness. Also, Padalino et al. [68] reported a similar finding on gluten-free spaghetti; as hydrocolloids were added, adhesiveness was lowered. Optimized *Kemesha* samples showed a significant increase in springiness compared to the control. Springiness indicates the ability of the *Kemesha* to return to its original shape after deformation. This could also be improved by using carboxymethyl cellulose (CMC) because the interactions among their polymer chains (hydrophobic interactions, hydrophilic interactions, as well as H-bonding) could provide elasticity or flexibility in the *Kemesha* [69].

In Table 8, cooking loss, water absorption, and volume gain are some of the qualities of the kemesha cooking process that are shown. It is preferable for *Kemesha* to have little leached solid in cooked water, indicating *Kemesha* with a compact texture. During cooking, the solid leached is widely used to indicate the overall cooking performance; the low amounts of residue indicate high-quality cooked *Kemesha*. Cooking loss is undesirable, and according to Ugarčić-Hardi et al. [70], it should not exceed 10 % of the dry weight. A significant decrease ($p < 0.05$) in the cooking loss was reported on the optimized *Kemesha*, containing 3.48 % carboxy methyl cellulose, as compared to the control *Kemesha*. While the cooking loss of optimized *Kemesha* was 4.95 % that of the control *Kemesha* was 7.25 %. The degree of *Kemesha* hydration can be measured as the water absorption capacity index. The optimized *Kemesha's* capacity to absorb water was higher than the control *Kemesha*'s, at 220.68 % versus 180.62 %, respectively. Comparing the functional *Kemesha* to the control, the volume rise increased significantly ($p < 0.05$), from 216.50 to 250.55 %. According to Cristina, Paes and Pereira [71] an ideal volume increase is found between 200 and 300 %, so the pasta is considered of good quality. With regard to this classification, all the samples presented good quality (Table 8). *Kemesha's* ideal cooking time was reduced from 6 min for the control to 5.3 min. Most probably, due to the dilution of gluten, the starch-protein network will be weakened and it facilitates water diffusion through the food matrix, reducing the time the water needs to reach the food center during the cooking process [72].

According to Gull, Prasad and Kumar [16], during cooking, soluble starch and other soluble components, including nonstarch polysaccharides, leach out into the water, and as a result, the cooked water becomes thick. According to Larrosa et al. [27], a high loss

Table 7
Physical properties control and optimized *Kemesha*.

Activities	Control	Optimized
L*	89.38 ± 2.24^{a}	74.44 ± 2.50^{b}
a*	0.35 ± 0.20^{b}	3.62 ± 0.35^{a}
b*	15.09 ± 2.24^{b}	31.09 ± 1.84^{a}
C*	15.09 ± 2.24^{b}	31.30 ± 1.84^{a}
H*	88.65 ± 0.76^{a}	83.35 ± 0.70^{b}
DE		22.31 ± 2.63^{a}
Water activity	0.46 ± 0.01^{a}	0.49 ± 0.02^{a}
pH	5.88 ± 0.06^{a}	5.91 ± 0.07^{a}

All values are mean ± standard deviation. This means sharing the same letters in raws are not significantly different from each other(student-t-test, $p < 0.05$). L*, whiteness; a*, redness; b*, yellowness; C*, chroma; H*, hue angle.

Table 8

Texture and Cooking properties of control and optimized *Kemesha*.

Activities	Control	Optimized
Hardness (g)	904.94 ± 68.91^{b}	1110.05 ± 59.93^{a}
Springiness	0.28 ± 0.06^{b}	0.54 ± 0.07^{a}
Cohesiveness	0.45 ± 0.09^{a}	0.31 ± 0.08^{b}
Adhesiveness (g*s)	24.94 ± 5.22^{a}	22.33 ± 2.70^{a}
Chewiness (g)	114.40 ± 33.00^{b}	181.80 ± 42.88^{a}
Water absorption (%)	180.62 ± 12.70^{b}	220.68 ± 8.33^{a}
Cooking loss (%)	7.25 ± 0.63^{a}	4.95 ± 0.18^{b}
Volume increase (%)	216.50 ± 10.98^{b}	250.55 ± 6.78^{a}
Cooking time (min)	6	5.3

All values are mean ± standard deviation. This means sharing the same letters in raws are not significantly different from each other (student-t-test, $p < 0.05$).

could be due to the absence of a protein reticule with a well-structured structure, which would prevent the excessive swelling of the starch granules and the ensuing dispersion of ingredients in the cooking water. But including carboxymethyl cellulose (CMC), which enhanced the gluten network and formed a matrix with the gluten proteins where starch granules were embedded and reduced the solid loss, may be responsible for this decrease in cooking loss [16,43]. Moreover, this might result from the strong network that forms between gum and starch, with the starch granules strongly adhering to the gum's surface [48]. Due to the inclusion of CMC, it was also reported by Chillo et al. [72] and Shiau [73] that the cooking loss of spaghetti decreased. Hydrocolloids can make pasta with a decent texture and less cooking loss, which is acceptable, according to Gull, Prasad, and Kumar [34]. So, these studies agree with the above finding and reported a positive effect of hydrocolloid addition on the cooking loss indicating a good *Kemesha* quality. The hydrophilic properties of gums may be the cause of the enhanced water absorption in the improved *Kemesha* [48,74,75].

Similar to this, it has been suggested by Kraithong and Rawdkuen [76] that hydrocolloids may improve the rehydration of noodles because of their strong capacity to bind or engulf water molecules via the hydroxyl groups of their polymer chains. In addition, the increased cooked weight may be due to water binding and water holding capacity of carboxy methyl cellulose and both the haricot and pumpkin flours. In similar studies on pasta by Ref. [71], if the minimum values of weight gain or water absorptions are 100 %, it is characterized as a good quality pasta; therefore, both optimized and control *Kemesha* presented a satisfactory water uptake.

3.12. Sensory properties of the control and optimized Kemesha

All the panelists have detected *Kemesha* characteristics on the basis of different properties, which are given in Table 9. An insignificant reduction in scores of the odor was observed for optimized *Kemesha* samples. The results of the sensory evaluation of dry uncooked samples indicate that optimized *Kemesha* significantly increased the scores of surface smoothness and resistance to break from 7.40 ± 1.07 to 8.40 ± 0.52 and 7.10 ± 1.20 to 8.20 ± 0.79, respectively. There was a significant difference between the control and the optimized *Kemesha* in terms of appearance and overall acceptability. The color, homogeneity, and resistance to break are the main ones responsible for the increase in the sample's overall quality. This result can be due to the fact that carboxymethyl cellulose (CMC) had a synergistic effect when blended with non-ionic polymer by providing a considerable increase in viscosity [1].

Cooked optimized *Kemesha* was perceived to have higher textural (8.20 ± 0.63), color (8.20 ± 0.92), and appearance (8.10 ± 0.57) acceptability than *Kemesha* prepared only from common wheat flour. The optimized *Kemesha* was perceived as having more yellow than the control *Kemesha*. A noticeable difference was observed in the appearance of optimized *Kemesha* as the color was yellowish and surface smoothness was higher in correlation to the control. Optimized *Kemesha* had higher scores in terms of overall liking as compared with the control due to the consequence of the pumpkin color and improvement in texture. The beany odor was not perceivable in control, whereas it was somewhat beany, and pumpkin flavor was perceivable on optimized *Kemesha*. The slight

Table 9

Sensory properties of raw and cooked control and optimized *Kemesha*.

Activities	Control	Optimized
Surface smoothness	7.40 ± 1.07^{b}	8.40 ± 0.52^{a}
Resistance to break	7.10 ± 1.20^{b}	8.20 ± 0.79^{a}
Odor	8.20 ± 0.92^{a}	7.50 ± 0.97^{a}
Appearance	7.50 ± 0.85^{b}	8.30 ± 0.67^{a}
OVA	7.30 ± 0.67^{b}	8.20 ± 0.92^{a}
Cooked *Kemesha*		
Texture	7.40 ± 0.97^{b}	8.20 ± 0.63^{a}
Color	7.30 ± 0.95^{b}	8.20 ± 0.92^{a}
odor	8.10 ± 0.57^{a}	7.40 ± 0.97^{a}
Appearance	7.30 ± 0.82^{b}	8.10 ± 0.57^{a}
OVA	7.20 ± 0.79^{b}	8.10 ± 0.74^{a}

All values are mean ± standard deviation. This means sharing the same letters in columns are not significantly different from each other(student-t-test, $p < 0.05$). ; OVA, Overall acceptability.

difference in the characteristic aromatic flavor of haricot bean and pumpkin flour to wheat flour could have been the reason for the odor of *Kemesha* samples.

Moreover, the structuring agents did not alter the odor of the samples, which was pleasant [1]. In general, the structuring agent has more affinity to starch and forms a stable polymeric network, which is important for the entrapment of carbohydrates and good *Kemesha* quality. The sensory properties of the spaghetti samples were found to be improved by Chillo et al. [72] and (L. Padalino et al. [1], who discovered that the presence of carboxymethyl cellulose (CMC) slows down the diffusion of amylose molecules from the internal part to the spaghetti surface. The spaghetti samples displayed good elasticity and firmness and low adhesiveness. Similarly, Yadav et al. [77] also observed an increase in overall acceptability with CMC for non-wheat pasta based on pearl millet flour containing barley and whey protein concentrate. In line with this study, Bharath Kumar and Prabhasankar [63] stated that noodles prepared with different cereal flours, vegetables, and pulses showed increased acceptability among consumers, with improved quality characteristics.

4. Conclusions

The chemical and physical properties of *Kemesha* formulations were effectively improved by including germinated haricot bean, ultrasonicated fine-milled pumpkin flour, and carboxymethyl cellulose (CMC), which improved *Kemesha* as a functional food. D-optimal mixture design was used to optimize the formulation of *Kemesha* with better nutritional, cooking, and sensory characteristics than the control sample. The optimal formulation contained 63.00 g of common wheat flour, 19.01 g of germinated haricot bean flour, 14.51 g of ultrasonicated fine-milled pumpkin flour, and 3.48 g of carboxymethyl cellulose per 100 g of flour. The amount of fibre and protein in the optimal sample was 3.85 and 1.31 times higher than the control *Kemesha,* respectively. Total phenolic, carotenoid, and antioxidant properties of optimized functional *Kemesha* were significantly higher than control *Kemesha* and may offer the inherent health benefits of pumpkin and germinated haricot bean, especially phytochemicals, to the consumer. This could substantially impact the increasing consumption of kemesha from underused crops like haricot beans and pumpkin flour, which are both functionally and nutritionally acceptable. Carboxymethyl cellulose (CMC) improved sensory and cooking quality aspects such as cooked loss, water absorption, and volume increase. It also raised hardness and lowered adhesiveness significantly ($P \leq 0.05$). The sensory evaluation results showed that color changes increased the overall liking of the optimized treatment compared to the control sample. The findings of this study could also give the food industry vital knowledge on the development of new functional foods and the possible use of underutilized pumpkin and haricot bean crops in food formulations. In general, this form of *Kemesha* will provide vital nourishment and health benefits, despite its intake not being widespread in the country.

Ethics statement

Kemesha is a traditional food that has been consumed by the local community for a generation. To conduct the sensory analysis, we selected Wolkite University Food Engineering staff who were familiar with *Kemesha* and provided them with an orientation on the principles of sensory analysis. In order to ensure ethical compliance, the following ethics statement outlines the measures taken, including obtaining consent and addressing other necessary ethical considerations.

The research protocol and procedures were reviewed and approved by the Wolkite University Research Ethics Committees. All participants were provided with comprehensive information regarding the purpose, procedures, and potential risks or discomfort associated with the sensory evaluation. They were given the opportunity to provide informed consent before participating. The sensory evaluation of traditional foods was carried out with utmost consideration for the cultural significance and heritage of the communities from which the foods originated. All data collected during the sensory evaluation were treated with strict confidentiality. Participant identities and any personal information were anonymized and used solely for research purposes. Participation in the sensory evaluation was voluntary, and participants had the right to withdraw from the study at any time without facing any negative consequences. Evaluators involved in the sensory evaluation adhered to professional conduct, maintaining respect, impartiality, and fairness throughout the process. Whenever feasible, endeavors will be made to share the benefits of the sensory evaluation of traditional foods with the communities involved. This may involve providing feedback, insights, or support for initiatives related to the preservation, promotion, or economic development of traditional foods.

Author contribution statement

Derese Wodajo Bekele: Conceived and designed the experiments; Performed the experiments; Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data; Wrote the paper.

Shimelis Admassu Emire: Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data; Wrote the paper.

Data availability statement

Data included in article/supp. material/referenced in article.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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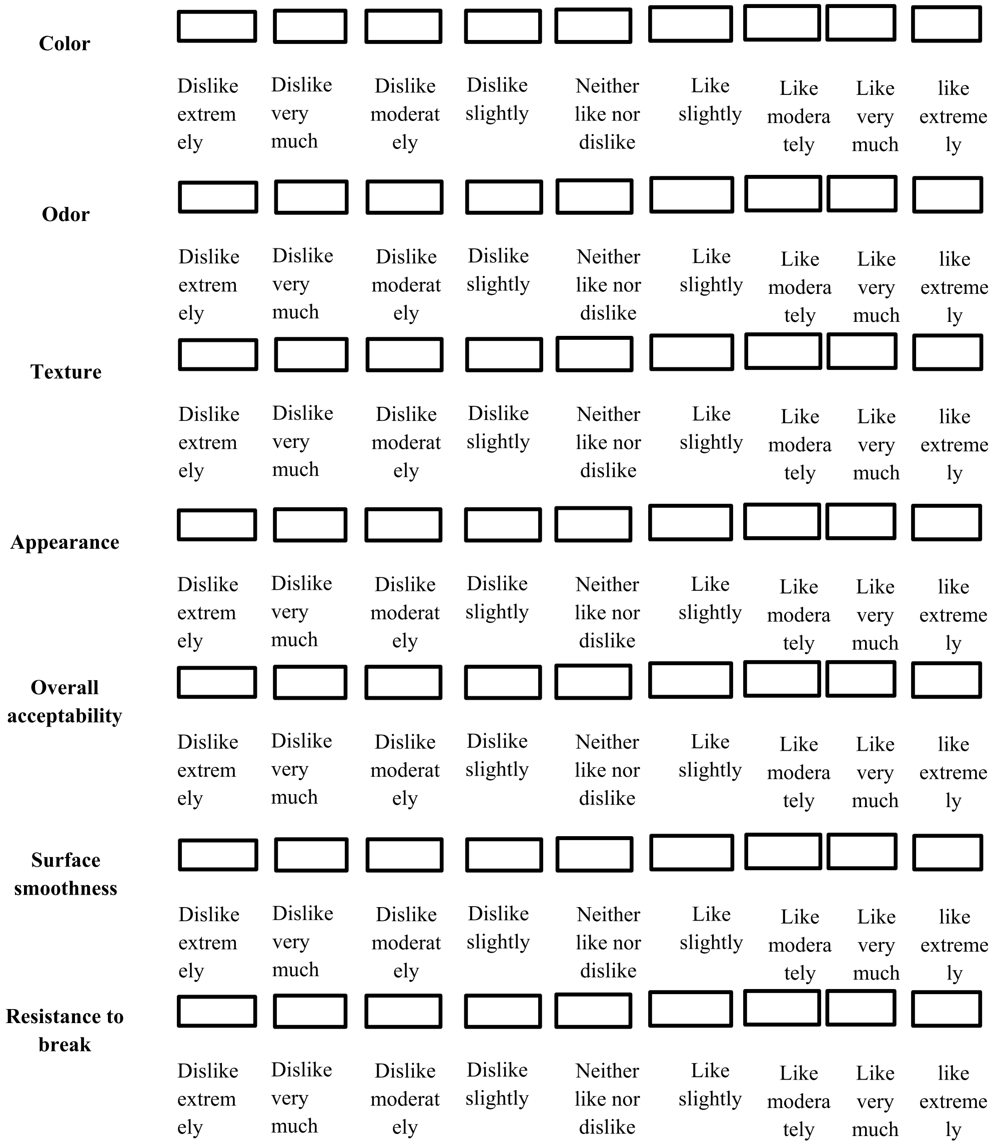
Appendix

Sensory evaluation sheet

Based on the provided criteria and your definition of good kemesha, rate the dried and cooked kemesha. Put the 'x' in the scale box that corresponds to the situation the best.



Color	☐ Dislike extremely	☐ Dislike very much	☐ Dislike moderately	☐ Dislike slightly	☐ Neither like nor dislike	☐ Like slightly	☐ Like moderately	☐ Like very much	☐ like extremely
Odor	☐ Dislike extremely	☐ Dislike very much	☐ Dislike moderately	☐ Dislike slightly	☐ Neither like nor dislike	☐ Like slightly	☐ Like moderately	☐ Like very much	☐ like extremely
Texture	☐ Dislike extremely	☐ Dislike very much	☐ Dislike moderately	☐ Dislike slightly	☐ Neither like nor dislike	☐ Like slightly	☐ Like moderately	☐ Like very much	☐ like extremely
Appearance	☐ Dislike extremely	☐ Dislike very much	☐ Dislike moderately	☐ Dislike slightly	☐ Neither like nor dislike	☐ Like slightly	☐ Like moderately	☐ Like very much	☐ like extremely
Overall acceptability	☐ Dislike extremely	☐ Dislike very much	☐ Dislike moderately	☐ Dislike slightly	☐ Neither like nor dislike	☐ Like slightly	☐ Like moderately	☐ Like very much	☐ like extremely
Surface smoothness	☐ Dislike extremely	☐ Dislike very much	☐ Dislike moderately	☐ Dislike slightly	☐ Neither like nor dislike	☐ Like slightly	☐ Like moderately	☐ Like very much	☐ like extremely
Resistance to break	☐ Dislike extremely	☐ Dislike very much	☐ Dislike moderately	☐ Dislike slightly	☐ Neither like nor dislike	☐ Like slightly	☐ Like moderately	☐ Like very much	☐ like extremely

References

[1] L. Padalino, M. Mastromatteo, G. Sepielli, M. Alessandro, D. Nobile, Formulation optimization of gluten-free functional spaghetti based on maize flour and oat bran enriched in β -glucans, Materials 4 (2011) 2119–2135.

[2] Ebru Eyidemir, M. Hayta, The effect of apricot kernel flour incorporation on the physicochemical and sensory properties of noodle, Afr. J. Biotechnol. 8 (1) (2009) 85–90.

[3] S. Harusekwi Julien, Development of fermented corn and rapoko blend instant porridge, Int. J. Nutr. Food Sci. 5 (4) (2016) 246.

[4] M. Meenu, et al., A detailed review on quality parameters of functional noodles, Food Rev. Int. 00 (2022) 1–37, 00.

[5] E. Betoret, N. Betoret, D. Vidal, P. Fito, Functional foods development: trends and technologies, Trends Food Sci. Technol. 22 (9) (2011) 498–508.

[6] D. Peressini, M. Foschia, F. Tubaro, A. Sensidoni, Impact of soluble dietary fibre on the characteristics of extruded snacks, Food Hydrocolloids 43 (2015) 73–81.

[7] V. Coman, et al., Bioactive potential of fruit and vegetable wastes, Adv. Food Nutr. Res. 91 (2020) 157–225.

[8] L. Padalino, et al., Functional pasta with tomato by-product as a source of antioxidant compounds and dietary fibre, Czech J. Food Sci. 35 (1) (2017) 48–56.

[9] D. Alemayehu, G. Desse, K. Abegaz, B.B. Desalegn, D. Getahun, Proximate, mineral composition and sensory acceptability of home made noodles from stinging nettle (urtica simensis) leaves and wheat flour blends, Int. J. Food Sci. Nutr. Eng. 6 (3) (2016) 55–61.

[10] M. Virginia, Nutritional and health benefits of dried beans, Am. J. Clin. Nutr. 100 (SUPPL. 1) (2014) 437S, 42S.

[11] D. Wodajo, S. Admassu, Haricot beans (Phaseolus vulgaris L .) flour : effect of varieties and processing methods to favor the utilization of underconsumed common beans, Int. J. Food Prop. 25 (1) (2022) 1186–1202.

[12] Derese Wodajo, S.A. Emire, Pumpkin flour qualities as affected by ultrasound and microwave pre-drying treatment, Int. J. Food Prop. 25 (1) (2022) 2409–2424.

[13] O.A. Olaoye, S.C. Ubbor, C.J. Okakpu, Use of composite flours of wheat and white beans (Phaseolus vulgaris) in bread making : influence on quality indices, Appl. Sci. Rep. 15 (3) (2016) 148–154.

[14] M. Mastromatteo, A. Danza, M. Guida, M.A. Del Nobile, Formulation optimisation of vegetable flour-loaded functional bread Part I : screening of vegetable flours and structuring agents, Int. J. Food Sci. Technol. 47 (2012) 1–8.

[15] N.T. Manyatsi, W.K. Solomon, J.S. Shelembe, N.T. Manyatsi, W.K. Solomon, J.S. Shelembe, Optimization of blending ratios of wheat-maize- sprouted mungbean (Vigna radiata L .) composite flour bread using D-optimal mixture design, Cogent Food Agric. ISSN 6 (1) (2020), 1824304.

[16] A. Gull, K. Prasad, P. Kumar, Nutritional, antioxidant, microstructural and pasting properties of functional pasta, J. Saudi Soc. Agric. Sci. 17 (2) (2018) 147–153.

[17] M. Siddiq, R. Ravi, J.B. Harte, K.D. Dolan, Physical and functional characteristics of selected dry bean (Phaseolus vulgaris L .) flours, LWT–Food Sci. Technol. 43 (2) (2010) 232–237.

[18] AOAC, Association of Official Analytical Chemists, seventeenth ed., 2005. Washington DC.

[19] C. Cappa, et al., Effects of red rice or buckwheat addition on nutritional, technological , and sensory quality of potato-based pasta, Food 10 (1) (2021) 91.

[20] V. Jayasena, S.M. Nasar-Abbas, Development and quality evaluation of high-protein and high-dietary-fiber pasta using lupin flour, J. Texture Stud. 43 (2) (2012) 153–163.

[21] A. Mirani, M. Goli, Production of the eggplant- fiber incorporated cupcake and evaluating its chemical , textural and colorimetric properties over a ten- day storage time, J. Food Process. Preserv. 45 (2021) 1–14.

[22] E.H. Erbiai, L. Pinto da Silva, R. Saidi, Z. Lamrani, J.C.G. Esteves da Silva, A. Maouni, Chemical composition, bioactive compounds and antioxidant activity of two wild edible mushrooms armillaria mellea and macrolepiota procera from two countries (Morocco and Portugal), Biomolecules 11 (4) (2021) 1–11.

[23] M. Minuye, P. Getachew, A. Laillou, S. Chitekwe, K. Baye, Effects of different drying methods and ascorbic acid pretreatment on carotenoids and polyphenols of papaya fruit in Ethiopia, Food Sci. Nutr. 9 (6) (2021) 3346–3353.

[24] A.Z. Woldegiorgis, D. Abate, G.D. Haki, G.R. Ziegler, Antioxidant property of edible mushrooms collected from Ethiopia, Food Chem. 157 (2014) 30–36.

[25] L.M.J. de Carvalho, et al., Total carotenoid content, α-carotene and β-carotene, of landrace pumpkins (Cucurbita moschata Duch): a preliminary study, Food Res. Int. 47 (2) (2012) 337–340.

[26] AACC, American Association for Clinical Chemistry- International Approved Methods of Analysis, eleventh ed., 2010. St. Paul, MN, USA.

[27] V. Larrosa, G. Lorenzo, N. Zaritzky, A. Califano, Improvement of the texture and quality of cooked gluten-free pasta, Lwt 70 (2016) 96–103.

[28] S.S. Alam, et al., Analysis of the physical and structure characteristics of reformulated pizza bread, Foods 11 (13) (2022) 1–13.

[29] J. Liu, J. Yin, Y. Zhang, L. Zhao, Y. Li, X. Zhou, Effect of carboxymethyl cellulose on rheological and textural properties of instant noodles, Int. J. Food Sci. Technol. 55 (55) (2020) 2066–2072.

[30] Y. Hu, Y. Huang, W. Tang, F. Chen, Impact of carboxymethyl cellulose on cooking and sensory properties of cooked noodles, J. Food Eng. 251 (2019) 46–53.

[31] M. Mariotti, S. Iametti, C. Cappa, P. Rasmussen, M. Lucisano, Characterisation of gluten-free pasta through conventional and innovative methods: evaluation of the uncooked products, J. Cereal. Sci. 53 (3) (2011) 319–327.

[32] L. Kamali Rousta, A. Pouya Ghandehari Yazdi, S. Khorasani, M. Tavakoli, Z. Ahmadi, M. Amini, Optimization of novel multigrain pasta and evaluation of physicochemical properties: using D-optimal mixture design, Food Sci. Nutr. 9 (10) (2021) 5546–5556.

[33] L.L. Battaiotto, C.E. Lupano, A.E. Bevilacqua, Optimization of basic ingredient optimization of basic ingredient combination for sandwich cookie filling using response surface methodology, Food Bioprocess Technol. 6 (2013) 1847–1855.

[34] A. Gull, K. Prasad, P. Kumar, Optimization and functionality of millet supplemented pasta, Food Sci. Technol. 35 (4) (2015) 626–632.

[35] C.F. Diedericks, V.A. Jideani, Physicochemical and functional properties of insoluble dietary fiber isolated from Bambara groundnut (vigna subterranea [L.] verdc.), J. Food Sci. 80 (9) (2015) 1933–1944.

[36] G. Kaur, S. Sharma, H.P.S. Nagi, P.S. Ranote, Enrichment of pasta with different plant proteins, J. Food Sci. Technol. 50 (5) (2013) 1000–1005.

[37] A. Lorusso, M. Verni, M. Montemurro, R. Coda, M. Gobbetti, C.G. Rizzello, Use of fermented quinoa flour for pasta making and evaluation of the technological and nutritional features, Lwt 78 (2017) 215–221.

[38] R.L. Shogren, G.A. Hareland, Y.V. Wu, Sensory evaluation and composition of spaghetti fortified with soy flour, J. Food Sci. 71 (6) (2006) 428–432.

[39] T. Bojňanská, H. Frančáková, M. Líšková, M. Tokár, Legumes – the alternative raw materials for bread production, J. Microbiol. 1 (2012) 876–886.

[40] K. Ma, M. C, V. P, S. Gk, S. Ad, Effect of pumpkin flour on the rheological characteristics of wheat flour and on biscuit quality, J. Food Process. Technol. 10 (10) (2019).

[41] B.M. Veena, S. Hb, U. Ravidra, Enhancement of nutritional quality of pasta by incorporating underutilized greens, J. Pharmacogn. Phytochem. 8 (4) (2019) 3118–3121.

[42] D. Çakmakçı, Ü.İ. Konak, Y. Yavuz Abanoz, Physical, nutritional, textural and sensory qualities of Turkish noodles produced with siyez wheat (Triticum monococcum), kale (Brassica oleracea var. acephala) and chia seed (Salvia hispanica L.), Food Heal 8 (1) (2022) 35–45.

[43] C.M. Tudorica, V. Kuri, C.S. Brennan, Nutritional and physicochemical characteristics of dietary fiber, J. Agric. Food Chem. 50 (2) (2002) 347–356.

[44] T. De Pilli, A. Derossi, C. Severini, Cooking quality characterisation of ‘spaghetti’ based on soft wheat flour enriched with oat flour, Int. J. Food Sci. Technol. 48 (11) (2013) 2348–2355.

[45] B. Gatta, M. Rutigliano, L. Padalino, A. Conte, A. Del Nobile, A. Di Luccia, The Role of Hydration on the Cooking Quality of Bran-Enriched Pasta Barbara, LWT - Food Sci. Technol., 2017.

[46] E.K. Parassih, E.Y. Purwani, W. El Kiyat, Optimisation of cassava dried noodle using hydrocolloid and protein isolates: a tropical noodle, Futur. Food J. Food, Agric. Soc. 8 (4) (2020) 1–84.

[47] C.S. Raina, S. Singh, A.S. Bawa, D.C. Saxena, Textural characteristics of pasta made from rice flour supplemented with proteins and hydrocolloids, J. Texture Stud. 36 (2005) 402–420.

[48] G. Widelska, et al., Impact of xanthan gum addition on phenolic acids composition and selected properties of new gluten- free maize-field bean pasta, Open Chem. 17 (2019) 587–598.

[49] İrem Toprakçı, E. Urtulbaş, A.G. Pekel, S. Şahin, Application of D-optimal design for automatic solvent extraction of carotenoid from orange peel, J. Food Process. Preserv. 45 (9) (2021) 1–8.

[50] N.I. Mohamad Zen, S.S. Abd Gani, R. Shamsudin, H.R. Fard Masoumi, The use of D-optimal mixture design in optimizing development of okara tablet formulation as a dietary supplement, Sci. World J. 2015 (2015).

[51] D.C. Kudake, A. V Pawar, A.B. Muley, Enrichment of wheat flour noodles with oat flour : effect on physical , nutritional , antioxidant and sensory properties, Int. J.Curr.Microbiol.App.Sci 6 (12) (2017) 204–213.

[52] P.D. Shere, A.N. Devkatte, V.N. Pawar, Studies on production of functional noodles with incorporation of spinach puree, Int. J. Curr. Microbiol. Appl. Sci. 7 (6) (2018) 1618–1628.

[53] N. Aukkanit, S. Sirichokworrakit, Effect of dried pumpkin powder on physical, chemical, and sensory properties of noodle, Proc. Acad. World 52nd Int. Conf. Los Angeles (1) (2016) 128–132.

[54] J. Alberto, et al., Effect of the addition of common bean flour on the cooking quality and antioxidant characteristics of spaghetti, J. Microbiol. Biotechnol. Food Sci. 2 (2) (2012) 730–744.

[55] J.L. Buttriss, C. Stokes, Dietary fiber and health: an overview, Nutr. Bull. 33 (2008) 186–200.

[56] K.N. Pakhare, A.C. Dagadkhair, I.S. Udachan, Enhancement of nutritional and functional characteristics of noodles by fortification with protein and fiber : a review, J. Pharmacogn. Phytochem. 7 (1) (2018) 351–357.

[57] J.A. Gallegos-infante, N.E. Rocha-guzman, R.F. Gonzalez-laredo, L.A. Ochoa-martínez, Quality of spaghetti pasta containing Mexican common bean flour (Phaseolus vulgaris L .), Food Chem. 119 (4) (2010) 1544–1549.

[58] I. Karkouch, et al., Antioxidant, antityrosinase and antibiofilm activities of synthesized peptides derived from Vicia faba protein hydrolysate: a powerful agents in cosmetic application, Ind. Crops Prod. 109 (May) (2017) 310–319.

[59] M.S. Fernandez-Panchon, D. Villano, A.M. Troncoso, M.C. Garcia-Parrilla, Antioxidant activity of phenolic compounds: from in vitro results to in vivo evidence, Crit. Rev. Food Sci. Nutr. 48 (7) (2008) 649–671.

[60] Y. Luo, J. Li, C. Xu, Z. Hao, X. Jin, Q. Wang, Impact of processing on in vitro bioavailability of phenols and flavonodis and antioxidant activities in faba bean (Vicia faba L.) andazuki bean (Vigna angularis L.), Legum. Res. 37 (5) (2014) 492–499.

[61] W. Han, S. Ma, L. Li, X.X. Wang, X.L. Zheng, Application and development prospects of dietary fibers in flour products, J. Chem. 2017 (2017).

[62] B. Biernacka, et al., Relationship between the properties of raw and cooked spaghetti - new indices for pasta quality evaluation, Int. Agrophysics 32 (2) (2018) 217–223.

[63] S. Bharath Kumar, P. Prabhasankar, A study on starch profile of rajma bean (Phaseolus vulgaris) incorporated noodle dough and its functional characteristics, Food Chem. 180 (2015) 124–132.

[64] T. Poonsri, S. Jafarzadeh, F. Ariffin, S.Z. Abidin, Improving Nutrition , Physicochemical and Antioxidant Properties of Rice Noodles with Fiber and Protein-rich Fractions Derived from Cassava Leaves 7 (4) (2019) 325–332.

[65] D. Setiady, M. Lin, F. Younce, B.A. Rasco, Incorporation of minced trout (Oncorhynchus mykiss) into egg-based noodles, J. Food Process. Preserv. 31 (2007) 480–491.

[66] S. Singh, A. Arora, B. Singh, Germination: a vital process to improve the nutritional quality of grains and legumes, J. Food Sci. Technol. 52 (2) (2015) 1418–1445.

[67] H. Oduro-Obeng, B.X. Fu, T. Beta, Influence of cooking duration on carotenoids, physical properties and in vitro antioxidant capacity of pasta prepared from three Canadian durum wheat cultivars, Food Chem. 363 (2021), 130016.

[68] L. Padalino, M. Mastromatteo, P. De Vita, D.B. Maria Ficco, M.A. Del Nobile, Effects of hydrocolloids on chemical properties and cooking quality of gluten-free spaghetti, Int. J. Food Sci. Technol. 48 (5) (2013) 972–983.

[69] S. Kraithong, S. Lee, S. Rawdkuen, The influence of hydrocolloids on the properties organic red jasmine rice noodles, namely on antioxidant activity, cooking, texture, and sensory properties, Starch/Staerke 71 (1–2) (2019) 1–9.

[70] Ž. Ugarčić-Hardi, M. Jukić, D.K. Komlenić, M. Sabo, J. Hardi, Quality parameters of noodles made with various supplements, Czech J. Food Sci. 25 (3) (2007) 151–157.

[71] M. Cristina, D. Paes, J. Pereira, Proximate composition and technological characteristics of dry pasta incorporated with micronized corn pericarp, Rev. Caatinga 30 (2) (2017) 496–502.

[72] S. Chillo, J. Laverse, P.M. Falcone, M.A. Del Nobile, Effect of carboxymethylcellulose and pregelatinized corn starch on the quality of amaranthus spaghetti, J. Food Eng. 83 (4) (2007) 492–500.

[73] S.Y. Shiau, Effects of emulsifiers on dough rheological properties and the texture of extruded noodles, J. Texture Stud. 35 (1) (2004) 93–103.

[74] N. Kaur, S. Sharma, D.N. Yadav, H. Bobade, B. Singh, Quality characterization of Brown rice pasta supplemented with vital gluten and hydrocolloides, Agric. Res. 6 (2) (2017) 185–194.

[75] L.B. Milde, P.S. Chigal, J.E. Olivera, K.G. González, Incorporation of xanthan gum to gluten-free pasta with cassava starch. Physical, textural and sensory attributes, Lwt 131 (2020), 109674.

[76] S. Kraithong, S. Rawdkuen, Effects of food hydrocolloids on quality attributes of extruded red Jasmine rice noodle, PeerJ 8 (2020).

[77] D.N. Yadav, S. Balasubramanian, J. Kaur, T. Anand, A.K. Singh, Non-wheat pasta based on pearl millet flour containing barley and whey protein concentrate, J. Food Sci. Technol. 51 (10) (2014) 2592–2599.